Estimates of Fish-, Spill-, and Sluiceway-Passage Efficiencies of Radio-Tagged Juvenile Steelhead and Yearling Chinook Salmon at The Dalles Dam, 1999

Final Report of Research

Prepared by:

Hal C. Hansel
John W. Beeman
Timothy D. Counihan
Jill M. Hardiman
Brad D. Liedtke
Marc S. Novick
John M. Plumb

U.S. Geological Survey
Western Fisheries Research Center
Columbia River Research Laboratory
5501 A Cook-Underwood Road
Cook, Washington 98605

Submitted to:

U.S. Army Corps of Engineers
Portland District
Planning and Engineering Division
Environmental Resources Branch
Robert Duncan Plaza
333 S.W. 1st. Avenue
Portland, Oregon 97204-3495

Submitted:

May 18, 2000

Executive Summary

In 1999, the U.S. Army Corps of Engineers (COE) contracted with the U.S. Geological Survey to determine spill and fish passage efficiencies at The Dalles Dam (TDA) during 30 and 64% continuous 24-h spill treatments. The percent spill was alternated every three days comprising four six-day test blocks during spring, 1999. Our specific objectives were to: 1) determine the proportion of radio-tagged juvenile steelhead (*Oncorhynchus mykiss*) and yearling chinook salmon (*O. tshawytscha*) passing through the spillway and powerhouse (via turbines or sluiceway) at TDA during the two different spill treatments and 2) obtain information on the behavior of radio-tagged fish in the near-dam area prior to passage for each spill treatment.

Dam Operations: The test conditions were similar to those proposed. Mean hourly percent spill during the 30% spill treatment ranged from 29.6 to 31.1% among blocks and the percentage of total discharge spilled during the 64% treatment ranged from 63.3 to 63.7% for the first 3 blocks and was 57.2% during last block.

Number of Fish Released and Detected: From 7 May through 29 May, we radio-tagged and released 479 juvenile steelhead and 469 yearling chinook salmon from Rock Creek, 23 km upstream from John Day Dam (JDA). An additional 300 juvenile steelhead and 297 yearling chinook salmon were tagged and released from the fish bypass facility at JDA. Telemetry receivers at TDA detected 81 and 89% of the juvenile steelhead released from Rock Creek and the juvenile fish bypass facility, respectively; 79% of the yearling chinook salmon from each release site were detected.

Travel Time, Arrival Time, and Approach Pattern: Median travel times of juvenile steelhead and yearling chinook salmon from the Rock Creek release site to the TDA near-dam forebay were 48 and 37 h, respectively. Median travel times from the JDA juvenile fish collection facility were 13 and 16 h. Due to the time of the releases and the variable length of time it took individual fish to reach the dam, the hour of arrival at TDA of both species was widely dispersed throughout the diel period. Sixty-seven percent of the juvenile steelhead and 73% of the yearling chinook salmon were first detected at the powerhouse during 30% spill, while the remaining fish were first detected at the non-overflow wall or the spillway. During 64% spill, the proportions of these species first detected at the powerhouse were 56 and 53%, respectively. Typically, more than 80% of each species were located in the upper 16 m of the water column when they were within about 10 m of the powerhouse during each spill treatment.

Behavior in the Near-Dam Forebay: Median residence times in the near-dam forebay prior to dam passage were influenced by a fishes hour of arrival, the percentage of total dam discharge being spilled at arrival, and the species. The median residence time of juvenile hatchery steelhead arriving at TDA during 30% spill was significantly longer than that of fish arriving during 64% spill (1.4 vs. 0.3 h, respectively). This difference was due to passage delays of juvenile steelhead arriving during the 30% spill/adult pattern (daytime condition). Median residence times of juvenile steelhead arriving during this condition ranged from 0.6 to 4.9 h, whereas median residence times of fish arriving during the 30% spill/juvenile pattern (nighttime condition) ranged from 0.1 to 0.4 h. The longer steelhead residence times associated with the

3

30% spill/adult pattern were related to fish size. Hatchery steelhead less than 201 mm in length had significantly shorter forebay residence times than fish greater than 200 mm in length (3.9 vs.0.7 h), suggesting that wild juvenile steelhead (typically < 200 mm) arriving at TDA during this spill condition may pass the dam more quickly than the larger hatchery fish.

Radio-tagged yearling chinook salmon arriving in the near-dam forebay passed TDA relatively quickly regardless of the percent spill, spill pattern, or the hour of arrival. Median residence times of juvenile chinook salmon during the various spill conditions were all less than 0.3 h.

General Route and Time of Passage: Increasing spill discharge from 30 to 64% increased juvenile steelhead and yearling chinook salmon passage through the spillway and decreased the proportions passed via other routes. During 30% spill, 9% of the tagged juvenile steelhead passed through the powerhouse, 25% passed through the sluiceway, and 66% passed through the spillway. In contrast, during 64% spill, 5% passed through the powerhouse, 9% passed through the sluiceway, and 86% passed through the spillway. Of the yearling chinook salmon that passed during 30% spill, 26% passed through the powerhouse, 22% passed through the sluiceway, and 52% passed through the spillway. Nine percent of the tagged juvenile chinook salmon passed through the powerhouse, 12% passed through the sluiceway, and 79% passed through the spillway during 64% spill. Increasing spill from 30 to 64% resulted in increases in overall spillway passage and increased the proportion of fish passing via the south half of the spillway.

The time of day that radio-tagged fish passed TDA was affected by their time of arrival

in the near-dam forebay and species-specific responses to dam operations. More than 90% of tagged juvenile chinook salmon and juvenile steelhead arriving at night, passed the dam under the test conditions present during their arrival, indicating little passage delay during any condition. However, 28% of juvenile steelhead arriving in the day during 30% spill delayed passage until the evening; steelhead arriving in the day during 64% spill did not exhibit this delay.

Fish-, Spill-, and Sluiceway-Passage Efficiencies: Juvenile steelhead fish passage efficiency (FPE) did not significantly differ between the 30 and 64% spill, but yearling chinook salmon FPE was significantly greater during 64% spill than 30% spill. Estimates of juvenile steelhead FPE were 91% during 30% spill and 95% during 64% spill. Juvenile chinook salmon FPE estimates were 73 and 91% during 30 and 64% spill, respectively. Fish passage efficiencies of juvenile steelhead were significantly greater than FPE of yearling chinook salmon during both spill treatments.

Juvenile steelhead and yearling chinook salmon spill passage efficiencies (SPE) were significantly greater during 64% spill than at 30% spill. We estimated juvenile steelhead SPE to be 66 and 86% during 30 and 64% spill, respectively; yearling chinook salmon SPE was 51 and 79%. Estimates of SPE differed significantly between species during both spill treatments, but during 64% spill the difference was less than 8%.

Unlike the trend in SPE, juvenile steelhead and yearling chinook salmon sluiceway passage efficiencies (SLPE) were significantly greater during 30% spill than during 64% spill. We estimated juvenile steelhead SLPE to be 25 and 9% during 30 and 64% spill, respectively.

Yearling chinook salmon SLPE was 22% during 30% spill and 12% during 64% spill. There were no significant differences between species-specific SLPE estimates.

Although a significantly greater proportion of juvenile steelhead and yearling chinook salmon passed through the spillway during 64% spill than during 30% spill, the 30% treatment was more effective per volume of water passing through the spillway. During 30% spill, the ratios of juvenile steelhead and yearling chinook salmon passing through the spillway to the proportion of water spilled (i.e., spill effectiveness) were 2.2:1 and 1.7:1, respectively. The ratios during 64% spill were 1.4:1 and 1.3:1. The different values (i.e., slopes) during each discharge indicate that the relation between SPE and percent discharge spilled is curvilinear and that SPE increases at a decreasing rate as the percentage of water being spilled increases.

Diel Effects on FPE, SPE, and SLPE

Diel changes in passage conditions produced by the combination of day vs. night effects and spill pattern effects (adult pattern during the day and juvenile pattern at night), in most instances, did not significantly affect FPE, SPE, or SLPE. However, since the two effects were confounded during the study, we were unable to examine them independently. Although FPE and SLPE were typically greater for the daytime spill conditions than the nighttime spill conditions, these differences were usually not significant. The only significant difference between diel estimates of FPE or SLPE were of juvenile steelhead passing the dam during 30% spill. No significant differences in SPE were found between the two spill patterns for either species. Changes in diel spill conditions appeared to have the greatest effect on the spillway passage location of radio-tagged fish. During 64% spill, 53 and 35% of the juvenile steelhead

6

passed through the southern and northern halves of the spillway, respectively, when there was an adult spill pattern, whereas 27 and 55% passed through these routes during the juvenile spill pattern. Similarly, 64 and 16% of the yearling chinook salmon passed through the southern and northern halves of the spillway during the adult spill pattern and 28 and 50% of the fish passed through these routes during the juvenile pattern. A similar, less pronounced, switch in spillway passage location of juvenile chinook salmon was evident between spill patterns during 30% spill, but no change was apparent in data from juvenile steelhead.

Introduction

A Supplemental Biological Opinion issued by the National Marine Fisheries Service (NMFS) recommended that spill volumes at dams on the Columbia and Snake rivers be maximized to increase juvenile salmonid (*Oncorhynchus* spp.) survival without exceeding the current total dissolved gas cap levels or other project-specific limitations (NMFS 1998). At The Dalles Dam (TDA), where it is believed that the spillway may not be a benign passage route during some spill conditions, the NMFS requested that spill volumes be limited to 64% of the total discharge pending the completion of ongoing studies of passage survival and spill efficiency and effectiveness.

Generally, a 1:1 relationship is assumed between the percent of total fish that pass through the spillway and the percentage of total river flow passing through the spillway (Whitney et al. 1987). However, it is estimated that spill effectiveness is greater than the 1:1 ratio at TDA and that a spill volume of 31% of total river flow is needed to achieve 80% FPE for spring and summer migrants (Whitney et al. 1997). Other studies at TDA have indicated that 30% spill may be just as effective at passing juvenile salmonids as spill levels near 60% of the total discharge (NMFS 1998). The spillway and the ice-trash sluiceway are currently the only non-turbine routes of fish passage through TDA.

In 1999, the U.S. Army Corps of Engineers (COE) contracted with the Biological Resources Division (BRD) of the U.S. Geological Survey to determine spill and fish passage efficiencies at TDA during 30 and 64% continuous 24-h spill treatments. Our specific objectives were to: 1) determine the proportion of radio-tagged juvenile steelhead (*O. mykiss*) and yearling chinook salmon (*O. tshawytscha*) passing through the spillway and powerhouse (both turbines

and sluiceway) at TDA during the two spill treatments and 2) obtain information about the

behavior of radio-tagged fish in the near-dam area prior to passage during each spill treatment.

Methods

Study Site

The Dalles Dam is located on the Columbia River at river km 307 (Figure 1). The dam consists of a single powerhouse of 22 turbine units and a single spillway of 23 tainter gates. The powerhouse is oriented parallel to river flow, but the spillway is perpendicular to river flow. The powerhouse and spillway are connected by a non-overflow wall oriented parallel to river flow. A navigation lock is located at the north end of the dam.
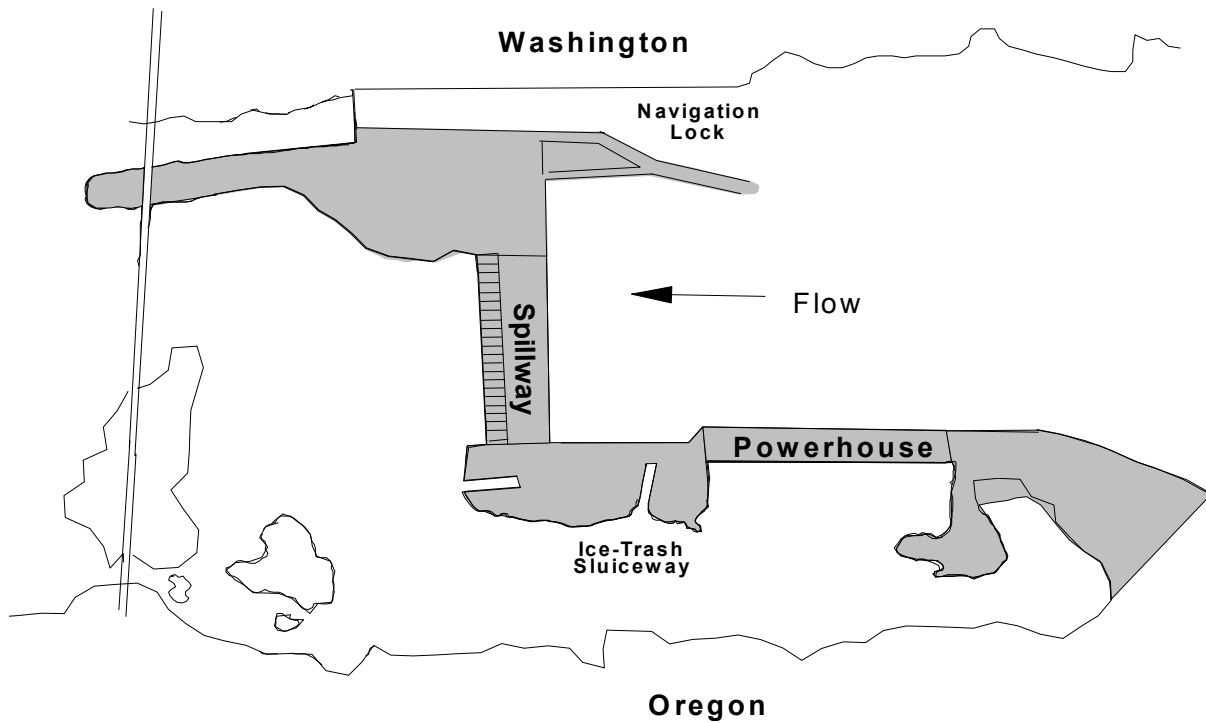
Figure 1. The Dalles Dam (river km 307) study site on the Columbia River.

Dam Operations

Each spill treatment (i.e., 30% or 64%) was implemented for three consecutive days within a 6-day block and was repeated for four blocks in the spring. Although the percent of the total dam discharge being spilled remained constant over a 24-h period within treatments, two different spill patterns were used during the course of a day to facilitate the passage of either juvenile or adult fish. The juvenile pattern was used at night to prioritize spill discharge through the northern spill bays, whereas the adult pattern used during the day resulted in higher spill volumes at the center of the spillway than at either end. Thus, there were four spill conditions possible during spring, 1999: 30% spill/adult pattern, 30% spill/juvenile pattern, 64% spill/adult pattern and 64% spill/juvenile pattern. Hourly powerhouse and spillway discharge data were obtained from the COE (1999).

Radio Transmitters and Fixed-Receiving Equipment

Pulse-coded transmitters were implanted in the juvenile steelhead and yearling chinook salmon allowing each individual fish to be recognized. Two sizes of these transmitters were used to accommodate the different sizes of the two species. Transmitters implanted in steelhead were 8.2 mm (diameter) x 18.9 mm and weighed 1.75 g in air, while the transmitters implanted in the yearling chinook salmon were 7.3 mm (diameter) x 18 mm and weighed 1.40 g in air.

Four-element Yagi (aerial) antennas were positioned along the periphery of the forebay to detect fish within about 100 m of the dam face, hereafter referred to as the near-dam area.

Each antenna monitored an area in front of a pair of turbine units or spillbays. These antennas were connected to Lotek SRX-400 receivers, which recorded the telemetry data, following the methods of Hensleigh et al. (1999). Additional aerial antennas were used to monitor the tailrace and area near the upstream boundary of the forebay boat-restricted zone. The SRX-400 was configured to scan all antennas combined (the master antenna), until it received a signal and then cycle through individual aerial antennas (auxiliary antennas) to determine a more precise location of the transmitter. Underwater antennas were used to monitor radio-tagged juvenile salmonids within about 10 m of each turbine unit or spillway tainter gate. Along the powerhouse, additional underwater antennas were also used to determine the vertical depth distribution of radio-tagged fish detected within about 10 m of the powerhouse. Up to seven underwater antennas were attached to a Lotek Digital Spectrum Processor in tandem with an SRX 400. The Digital Spectrum Processor allows simultaneous monitoring of all antennas and pulse-coded transmitters.

Fish Tagging, Handling, and Release

This study was conducted concurrently with a similar fish passage study at John Day Dam (JDA) and fish released above JDA for that study were monitored at TDA as well. For the JDA study, approximately 240 fish per 6-day block (120 fish per each spill treatment) were released with about equal numbers of juvenile steelhead and yearling chinook salmon in each release. In addition to these fish, about 150 juvenile steelhead and yearling chinook salmon were released through the JDA juvenile fish bypass per block (75 fish per spill treatment) to supplement the number of fish arriving at TDA. Within a block, four releases (20-40 fish per

release) per spill treatment were made at Rock Creek (23 km upstream from JDA) and two releases (37-38 fish per release) per spill treatment were made through the juvenile bypass system at JDA. In order to disperse the arrival of radio-tagged fish at TDA over the diel period, they were divided equally between day and night releases that occurred generally at 0800 and 2000 h at Rock Creek and at 0900 and 2100 h at the juvenile bypass collection facility.

Juvenile steelhead and yearling chinook salmon to be implanted with radio transmitters were obtained from the juvenile collection and bypass facility operated by the National Marine Fisheries Service at JDA. Fish to be implanted were either transported to the release site upriver of JDA at Rock Creek or kept at the collection facility and typically held 24-36 h prior to tagging. Fish were considered suitable for tagging if they were free of injuries, severe descaling, external signs of gas bubble trauma, or other abnormalities. Transmitters were surgically implanted in both species using the methods of Adams et al. (1998).

Following tagging, fish were held in river at Rock Creek or in tanks at the juvenile bypass collection facility for 20-24 h. After the holding period, the tanks were checked for mortalities and then towed by boat out into the north river channel (Rock Creek releases) where the fish were released or they were released through the juvenile bypass system (JDA releases).

Data Management and Analysis

Data from fixed receivers were typically downloaded every other day and imported into SAS (SAS Institute Inc., Cary, NC, USA) for subsequent proofing and analyses. The data were proofed to eliminate non-valid records including background noise, single records of a particular channel and code, records that were collected prior to the known release date and time, and

records known to be fish eaten by avian predators. Generally, the minimum amount of data required to validate the presence of a radio-tagged fish was a combination of two master antenna and one auxiliary antenna detections or three master antenna detections, within about 1-2 min of each other.

The location and time an individual fish was first detected by telemetry receivers on the dam face was considered the route and time of entrance into the near-dam area. Similarly, the last detection of an individual fish on the receivers on the dam face was considered the route and time of passage through the dam. However, radio-tagged fish were often detected on multiple auxiliary antennas where zones of coverage overlapped, making data reduction necessary. Fish detected on more than one aerial auxiliary antenna within a two-minute period at the time of passage were assigned to a single passage location corresponding to the antenna where the highest strength signal was recorded, and all other records were excluded. A two-minute interval was chosen because it approximately coincided with the upper boundary of time needed to complete a scan cycle if several fish were present at any given time. Manual tracking on the dams has verified that the last detection by telemetry receiving stations is typically a good estimate of the passage route (Sheer et al. 1997; Holmberg et al. 1998; Hensleigh et al. 1999). Juvenile steelhead and yearling chinook salmon approach and passage patterns during the various near-dam areas were compared between spill patterns using a Chi-square test. For this test and others throughout this report, results were considered statistically significant when $P \leq 0.05$.

Residence time in the near-dam area, defined as the amount of time between the first and last detections in the forebay, was calculated for each radio-tagged fish detected in the near-dam

forebay area (residence times were not calculated for fish detected only at entrance and exit stations). These residence times are a minimum estimate of the actual time that radio-tagged fish spent in the near-dam area because fish may have been in the near-dam area for an unknown amount of time prior to their first detection and following their last detection. Median forebay residence times of radio-tagged fish arriving at TDA during a particular spill condition (e.g., 30% spill/adult pattern) were compared statistically to those arriving under other spill conditions within and between species using a Kruskal-Wallis test. Within a particular day or nighttime spill period, median residence times were also calculated for a series of time intervals to determine the effect of time of arrival on residence time.

Fish passage efficiency was determined as the proportion of the total number of radio-tagged juvenile steelhead or yearling chinook salmon exiting the near-dam TDA forebay that passed via non-turbine routes (i.e., through the spillway or the ice-trash sluiceway). Similarly, spill passage efficiency (SPE) and sluiceway passage efficiency (SLPE) was calculated as the proportion of the total number of radio-tagged juvenile steelhead or yearling chinook salmon that passed through the spillway or sluiceway, respectively. Ninety-five percent confidence limits around estimates of FPE, SPE, and SLPE were calculated using the Fisher and Yates relationship between the F distribution and the binomial distribution (Zar 1996). The FPE, SPE, and SLPE (proportion) for the two spill discharges were compared (e.g., HO: $FPE_1=FPE_2$) within and between species using the Fisher Exact Test (Zar 1996). The statistical power, or probability of rejecting the null hypothesis when it was in fact false, was derived using computations based on approximations to the Fisher Exact test (Zar 1996). Spill effectiveness was calculated as SPE divided by the proportion of total dam discharge being spilled. This index was used to help

identify potential relations between spill discharges, FPE or SPE estimates, and juvenile

salmonid passage behavior.

<center>**Results and Discussion**</center>

Dam Operations

The mean hourly percent spill discharges at TDA during the spring were similar to those proposed during the design phase of the study (Table 1). Mean hourly percent spill during the 30% spill treatment ranged from 29.6 to 31.1% among blocks. Mean hourly percent spill during the 64% spill treatment ranged from 63.3 to 63.7% for the first three blocks and was 57.2% during block four (Table 1). Mean hourly total discharge ranged from 253 thousand cubic feet per second (KCFS) to 364 KCFS during the study, but differed by no more than 26 KCFS between treatments within each block (Table 1).

Table 1. Mean hourly percentages of total discharge spilled and mean hourly total discharge (KCFS) at The Dalles Dam for four 6-day blocks, 7 May through 31 May 1999. Each block consisted of one 3-day treatment of 30% 24-h spill discharge followed by a second 3-day treatment of 64% 24-h spill discharge.

Block	Mean Hourly Percent spill discharge	Mean hourly total discharge
1	30.0	264.3
1	63.3	263.6
2	29.6	254.1
2	63.7	259.2
3	30.2	274.1
3	63.3	252.8
4	31.1	337.9
4	57.2	364.4

Number of Fish Released and Detected

From 7 May through 29 May we radio-tagged and released 479 juvenile steelhead and 469 yearling chinook salmon (spring migrants) from the upriver release site at Rock Creek and an additional 300 juvenile steelhead and 297 yearling chinook salmon from the fish bypass facility at JDA (Table 2). Juvenile steelhead had a mean fork length of 214 mm (range 117 to 287 mm) and mean weight of 86 g (range 29 to 227 g). Yearling chinook salmon had a mean fork length of 166 mm (range 123 to 246 mm) and a mean weight of 48 g (range 19 to 168 g; Appendices A1 to A4). Fixed-receiving stations at the dam detected 81 and 89% of the juvenile steelhead released from Rock Creek and the juvenile fish bypass facility, respectively; 79% of the yearling chinook salmon from both release sites were detected (Table 2). Eighty-four percent of the juvenile steelhead and 79% of the yearling chinook salmon were detected overall.

Table 2. Number of radio-tagged juvenile steelhead and yearling chinook salmon released 23 km above John Day Dam (JDA) at Rock Creek and through the JDA juvenile fish bypass, and the percent of fish detected by telemetry receivers at The Dalles Dam, spring 1999.

Release site	Juvenile steelhead		Yearling chinook		Total	
	Number released	Percent contacted	Number released	Percent contacted	Number released	Percent contacted
Rock Creek	479	81.2	469	78.9	948	80.1
JDA Bypass	300	88.7	297	79.1	597	83.9
Overall	779	84.1	766	79.0	1545	81.5

Arrival Time and Approach Pattern

The hour of arrival at TDA of both species was widely dispersed throughout the diel

period (Figure 2). However, there was a peak in the arrival distribution of juvenile steelhead

between the hours of 0800 and 1159 (Figure 2). Juvenile steelhead and yearling chinook salmon

median travel times from the Rock Creek release site to the TDA near-dam forebay were 48 and

37 h, respectively; median travel times from the JDA juvenile fish collection facility were 13 and

16 h.
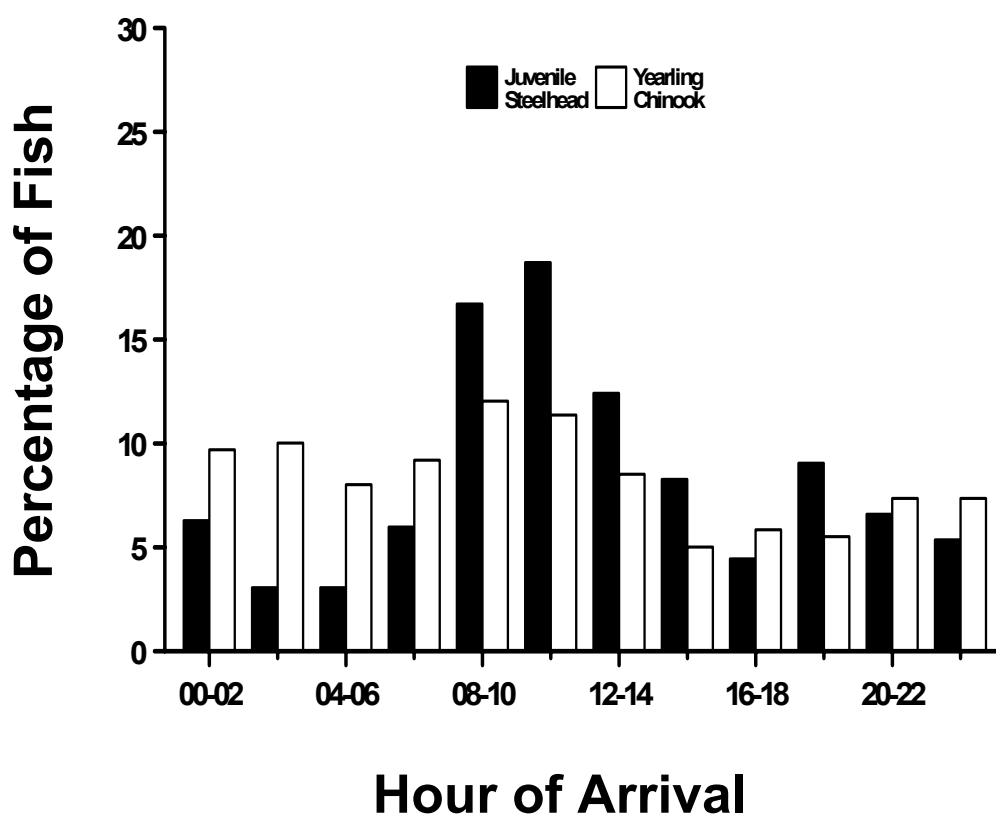
Figure 2. Diel distribution of radio-tagged juvenile steelhead and yearling chinook salmon
arrival in the near-dam forebay of The Dalles Dam among 2-h time intervals, spring 1999.
Sample sizes: juvenile steelhead = 598; yearling chinook = 652.

The area of first detection at the TDA forebay (i.e., powerhouse, non-overflow wall, or

spillway) differed significantly within species during 30 and 64% spill (Chi-Square test, P=0.005

and <0.001, respectively; Figure 3). However, no significant differences in first detection area

were detected between species during either spill treatment (P=0.17 and 0.85). Sixty-seven

percent of the juvenile steelhead and 73% of the yearling chinook salmon were first detected at
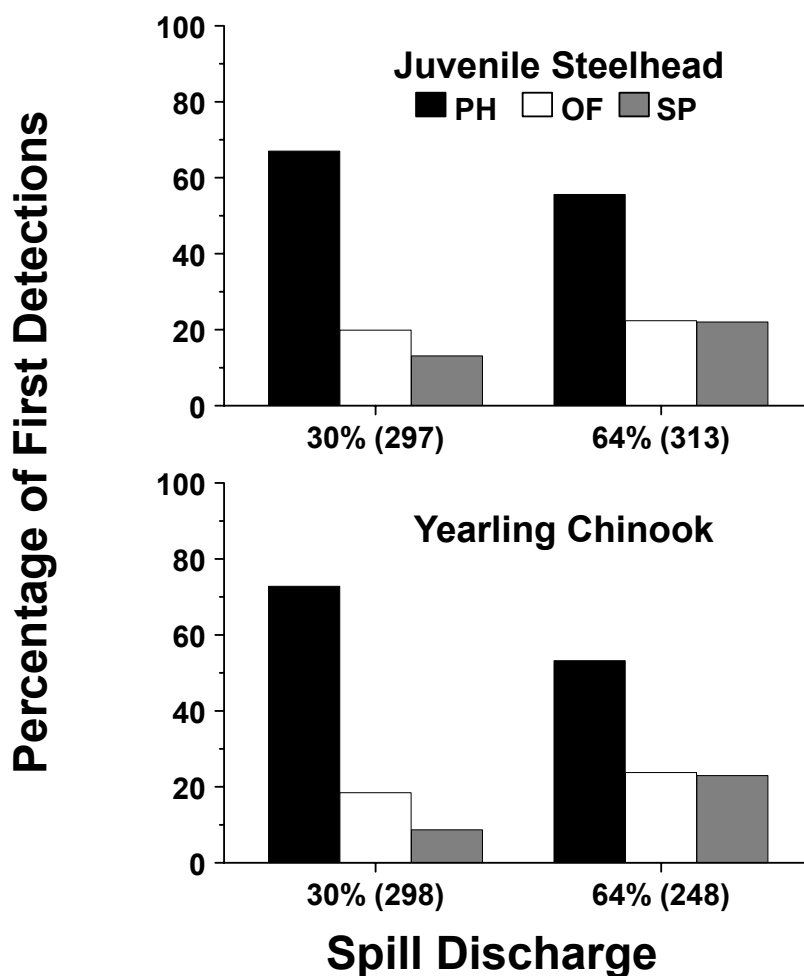
Figure 3. Distribution of steelhead and yearling chinook salmon first detections among the powerhouse (PH), non-overflow wall (OF), and spillway (SP) telemetry receivers in The Dalles Dam near-dam forebay for two different spill discharges, spring 1999. Spill discharges: 30%=30% 24-h spill discharge; 64%=64% 24-h spill discharge. Sample sizes are in parentheses.

the powerhouse during 30% spill, but these proportions were reduced to 56 and 53% when the

percent spill was increased to 64% and a greater proportion of first detections occurred at the

non-overflow wall and the spillway (Figure 3). Most (> 80%) of both species detected within 10

m of the powerhouse with underwater antennas were located in the upper 16 m of the water column during each spill treatment (Figure 4). Yearling chinook salmon were located at greater depths than juvenile steelhead during 30% spill, but these differences were less distinct during 64% spill (Figure 4). Both species were deepest near turbine units 2 to 5 and 8 to 13, possibly due to differences in turbine discharge (Figure 4).

Figure 4. Depth (m) distribution of radio-tagged juvenile steelhead and yearling chinook salmondetected within 10 meters of the The Dalles Dam turbine units during 30 and 64% spill discharge, spring 1999. Units 6 through 22 were not monitored at the 21 to 33 m depth.
Behavior in the Near-Dam Forebay
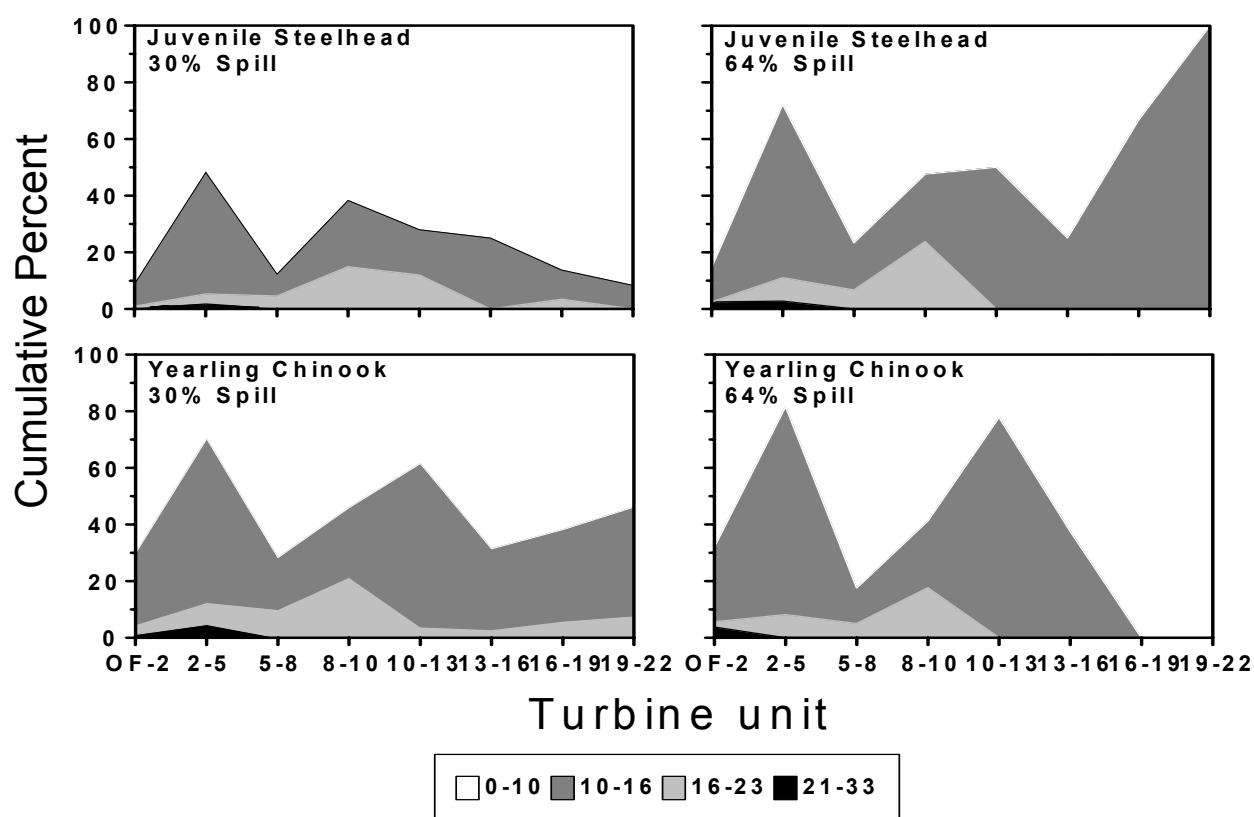
The amount of time radio-tagged fish spent in the near-dam forebay before passing was influenced by a fishes hour of arrival at the dam, the percentage of total dam discharge spilled at arrival, and the species (Table 3). The median residence time of juvenile steelhead

arriving at TDA during 30% spill was significantly longer than the median residence time of

fish arriving during 64% spill (1.4 vs. 0.3 h; Kruskal-Wallis test, P<0.001). This difference was

mainly due to juvenile steelhead arriving during 30% spill/adult pattern delaying passage for a

significantly longer time than those arriving during the juvenile spill pattern at that discharge

(2.2 vs. 0.3 h; P<0.001; Table 3). Median residence times of juvenile steelhead arriving during

30%

Table 3. Median forebay residence times (h) of radio-tagged juvenile steelhead and yearling
chinook salmon by time of arrival for two different 24-h spill discharges at The Dalles dam,
spring 1999. Spill discharge: 30%=30% 24-h spill; 64%=64% 24-h spill discharge. Sample
sizes are shown in parentheses.

Time of Arrival	Spill Pattern	Juvenile steelhead		Yearling chinook	
		30%	64%	30%	64%
0500-0759	Adult	0.6 (24)	0.3 (30)	0.3 (40)	0.2 (35)
0800-1059		2.0 (84)	0.3 (84)	0.2 (47)	0.2 (51)
1100-1359		4.9 (64)	0.4 (68)	0.3 (49)	0.3 (26)
1400-1659		3.4 (38)	0.2 (29)	0.3 (22)	0.2 (27)
1700-1959		1.9 (31)	0.4 (33)	0.3 (23)	0.3 (22)
Pooled		2.3 (241)	0.3 (244)	0.3 (181)	0.2 (161)
2000-2259	Juvenile	0.4 (32)	0.2 (31)	0.3 (35)	0.2 (27)
2300-0159		0.1 (16)	0.1 (22)	0.2 (43)	0.1 (26)
0200-0459		0.1 (6)	0.3 (13)	0.2 (37)	0.1 (33)
Pooled		0.3 (54)	0.2 (66)	0.3 (115)	0.1 (86)
Overall		1.4 (295)	0.3 (310)	0.3 (296)	0.2 (247)

spill/adult pattern ranged from 0.6 to 4.9 h, whereas median residence times of fish arriving

during 30% spill/juvenile pattern ranged from 0.1 to 0.4 h (Table 3). The median residence time

of juvenile steelhead arriving at the forebay during 64% spill/adult pattern was also significantly

longer than those arriving during the juvenile spill pattern at that discharge (0.3 vs. 0.2 h;

P<0.001), but the difference was less than 7 minutes. Median residence times for all 2-h

intervals over a 24-h period were # 0.4 h (Table 3).

The longer residence times of radio-tagged hatchery steelhead arriving during 30%

spill/adult pattern were related to fish size. Fish less than 201 mm in fork length (FL) had

significantly shorter forebay residence times than fish greater than 200 mm FL (0.7 vs. 3.9 h;

P<0.001). These data suggest that wild juvenile steelhead (typically < 200 mm FL) arriving at

TDA during similar spill conditions may pass the dam more quickly than their larger hatchery

counterparts do.

Radio-tagged yearling chinook salmon arriving in the near-dam forebay passed TDA

relatively quickly independent of the spill treatment or the hour of their arrival (Table 3). The

median residence time of fish arriving during 30% spill was significantly longer than fish

arriving during 64% spill, but the difference was less than 7 minutes (0.3 vs. 0.2 h; Kruskal-

Wallis test, P<0.001). Differences in median residence times of yearling chinook salmon

arriving during the adult or juvenile spill pattern within the 30 and 64% spill treatments were

less than 7 minutes (0.3 vs. 0.3 h and 0.2 vs. 0.1 h, respectively). The difference was not

statistically significant during 30% spill (P=0.65), but it was at 64% spill (P=0.05).

General Route and Time of Passage

The passage distribution of radio-tagged juvenile steelhead and yearling chinook salmon

among the powerhouse, sluiceway, and spillway areas differed between the 30 and 64% spill

treatments (Chi-square tests, blocks 1-4 pooled, both P=0.001; Figure 5). Of the juvenile

steelhead passing the dam during 30% spill, 9% passed through the powerhouse, 25% passed

through the sluiceway, and 66% passed through the spillway. In contrast, 5% passed through

the powerhouse, 9% passed through the sluiceway, and 86% passed through the spillway during

64% spill. Decreases in sluiceway and powerhouse passage during 64% spill were accompanied

by an increase in the proportion of juvenile steelhead passing through the southern end of the

spillway

(Figure 5).
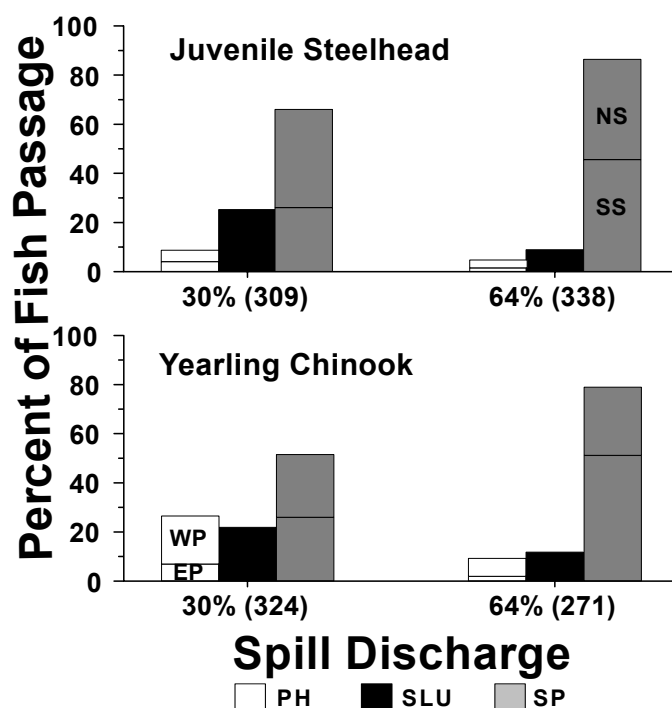
Figure 5. Percentage of juvenile steelhead and yearling chinook salmon passing The Dalles Dam
through the powerhouse (PH), sluiceway (SLU), and spillway during 30 and 64% spill dis-
charges, spring 1999. EP=east powerhouse; WP=west powerhouse; SS=south spillway;
NS=north spillway.

Turbine passage of yearling chinook salmon was higher and their spillway passage was

lower than those of juvenile steelhead during 30% spill. Of the yearling chinook salmon that

passed during 30% spill, 26% passed through the powerhouse, 22% passed through the

sluiceway, and 52% passed through the spillway (Figure 5).   The proportions of yearling

chinook salmon passing TDA via the spillway, powerhouse, or sluiceway were similar to those

of juvenile steelhead during 64% spill. During this treatment, 9% of the fish passed through the

powerhouse, 12% passed through the sluiceway, and 79% passed through the spillway. As with

juvenile steelhead, 64% spill resulted primarily in an increased proportion of fish passing via the

southern end of the spillway with concurrent decreases in sluiceway and turbine passage (Figure

5).

The time of day that radio-tagged fish passed TDA was determined by the hour of their

arrival in the near-dam forebay and species-specific responses to dam operations encountered at

that time (Figure 6). Yearling chinook salmon delays in the forebay prior to passage were short

during both 30 and 64% spill, resulting in similar diel distributions of arrival and passage. This

was also the case for juvenile steelhead passing during 64% spill, but the diel distribution of hour

of passage was shifted to the right of the hour of arrival for fish passing during 30% spill,

because steelhead arriving during the daytime commonly remained in the forebay for several

hours. Overall, however, the diel passage conditions during which both species passed were

dependent on the conditions during which they arrived (Fisher Exact Test, All P>0.001). Except

for juvenile steelhead arriving during 30% daytime spill, greater than 90% of both species passed

during the same diel spill conditions that were present when they arrived. Twenty-eight percent

of tagged juvenile steelhead arriving in the day during 30% spill delayed passage until nighttime.
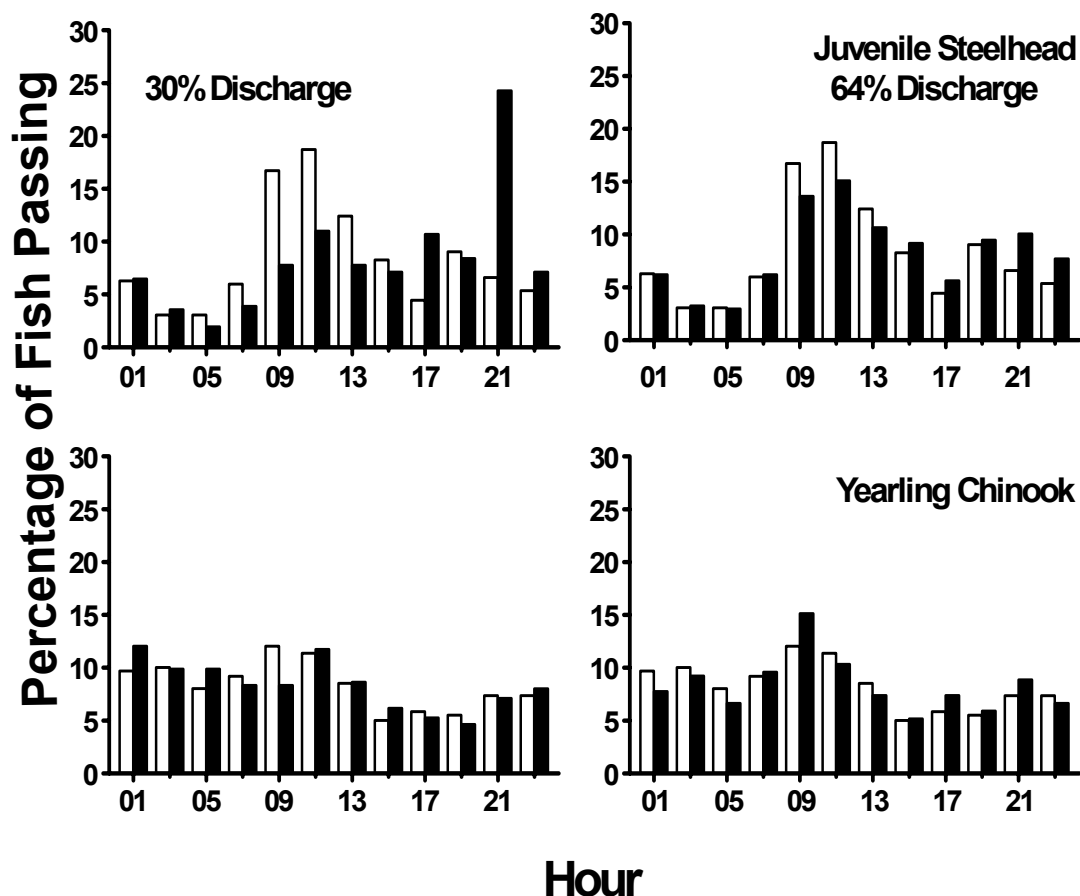
Figure 6. Diel distribution of radio-tagged juvenile steelhead and yearling chinook salmon passage (black bars) compared with the diel distribution of arrival (white bars) in the near-dam forebay of The Dalles Dam during 30 and 64% spill discharges, spring 1999. Hours are midpoints of 2-h intervals.

Fish-, Spill-, and Sluiceway-Passage Efficiencies

Juvenile steelhead FPE did not significantly differ between 30 and 64% spill treatments, but yearling chinook salmon FPE was significantly higher during 64% spill than during 30% spill (Fisher Exact tests, blocks 1-4 pooled; Table 4). We estimated juvenile steelhead FPE (blocks 1-4 pooled) to be 91% during 30% spill and 95% during the 64% spill. Juvenile chinook salmon FPE was 73 and 91% at 30 and 64% spill, respectively (Table 4). Fish passage efficiency of juvenile steelhead was significantly greater than FPE of yearling chinook salmon

during both treatments (Fisher Exact tests, blocks 1-4 pooled, P<0.001 and P=0.03). The

pooled-species FPE was greater during 64% spill than at 30% spill (93 vs. 82%; Table 4).

However, since the number of steelhead and yearling chinook in the sample were about equal,

these estimates do not necessarily represent what might be obtained for a run-of-river species

mix.

Table 4. Estimates ($p_{30\%}$ and $p_{64\%}$) of fish passage efficiency (FPE) for juvenile steelhead (STH), yearling chinook salmon (CH1), and both species combined (ALL) during two different spill discharges at The Dalles Dam, spring 1999. Spill discharges: 30%=30% 24-h spill discharge; 64%=64% 24-h spill discharge. CI=confidence interval. N=sample size. Significant differences (*) in FPE between the spill levels were evaluated using the Fisher Exact test (α=0.05).

| | | Spill Discharge | | | | | | | |
| | | 30% | | | 64% | | | (HO:$p_{30\%}$=$p_{64\%}$) | |
	Block	$p_{30\%}$	95% CI	N	$p_{64\%}$	95% CI	N	P	Power
STH	1	78.6	65.6-88.4	56	92.9	85.1-97.3	84	0.02*	0.68
	2	89.4	79.4-95.6	66	96.1	88.9-99.2	76	0.19	0.34
	3	94.6	86.7-98.5	74	97.5	91.4-99.7	81	0.43	0.16
	4	96.5	91.2-99.0	113	94.8	88.4-98.3	97	0.74	0.10
	Pooled	91.3	87.5-94.2	309	95.3	92.4-97.3	338	0.06	0.53
CH1	1	71.0	58.8-81.3	69	88.1	77.8-94.7	67	0.02*	0.70
	2	80.0	69.6-88.1	80	94.2	87.0-98.1	86	0.01*	0.79
	3	68.6	57.7-78.2	86	93.5	82.1-98.6	46	<0.01*	0.95
	4	74.2	63.8-82.9	89	87.5	77.6-94.1	72	0.05*	0.57
	Pooled	73.5	68.3-78.2	324	90.8	86.7-93.9	271	<0.01*	1.00
ALL	1	74.4	65.8-81.8	125	90.7	84.9-94.8	151	<0.01*	0.95
	2	84.2	77.3-89.7	146	95.1	90.5-97.8	162	<0.01*	0.89
	3	80.6	73.6-86.4	160	96.1	91.1-98.7	127	<0.01*	0.99
	4	86.6	81.2-91.0	202	91.7	86.5-95.4	169	0.14	0.34
	Pooled	82.1	78.9-85.1	633	93.3	91.0-95.1	609	<0.01*	1.00

Both juvenile steelhead and yearling chinook salmon SPE were significantly greater

during 64% spill than during 30% spill (blocks 1-4 pooled; Table 5). We estimated juvenile

steelhead SPE to be 66 and 86% during 30 and 64% spill, respectively; yearling chinook salmon

SPE was 51 and 79%. Estimates of SPE differed significantly between species during both spill

treatments, but the difference was less than 8% at 64% spill (Fisher Exact test, blocks 1-4

pooled, P<0.001 at 30% spill, P=0.02 at 64% spill). The pooled-species SPE was significantly

lower

Table 5. Estimates ($p_{30\%}$ and $p_{64\%}$) of spill passage efficiency (SPE) for juvenile steelhead
(STH), yearling chinook salmon (CH1), and both species combined (ALL) during two different
spill discharges at The Dalles Dam, spring 1999. Spill discharges: 30%=30% 24-h spill
discharge; 64%=64% 24-h spill discharge. CI=confidence interval. N=sample size. Significant
differences (*) in SPE between the spill levels were evaluated using the Fisher Exact test
(α=0.05).

| $p_{64\%}$) | | Spill Discharge | | | | | | (HO:$p_{30\%}$= | |
| | | 30% | | | 64% | | | | |
	Block	$p_{30\%}$	95% CI	N	$p_{64\%}$	95% CI	N	P	Power
STH	1	60.7	46.8-73.5	56	85.7	76.4-92.4	84	< 0.01*	0.92
	2	54.5	41.8-66.9	66	85.5	75.6-92.5	76	< 0.01*	0.99
	3	60.8	48.8-72.0	74	93.8	86.2-98.0	81	< 0.01*	1.00
	4	78.8	70.1-85.9	113	81.4	72.3-88.6	97	0.73	0.07
	Pooled	66.0	60.4-71.3	309	86.4	82.3-89.9	388	< 0.01*	1.00
CH1	1	49.3	37.0-61.6	69	79.1	67.4-88.1	67	< 0.01*	0.96
	2	58.8	47.2-69.6	80	84.9	75.5-91.7	86	< 0.01*	0.97
	3	50.0	39.0-61.0	86	84.8	71.1-93.7	46	< 0.01*	0.99
	4	48.3	37.6-59.2	89	68.1	56.0-78.6	72	0.02*	0.71
	Pooled	51.5	46.0-57.1	324	79.0	73.6-83.7	271	< 0.01*	1.00
ALL	1	54.4	45.3-63.3	125	82.8	75.8-88.4	151	< 0.01*	1.00
	2	56.8	48.4-65.0	146	85.2	78.8-90.3	162	< 0.01*	1.00
	3	55.0	46.9-62.9	160	90.6	84.1-95.0	127	< 0.01*	1.00
	4	65.3	58.3-71.9	202	75.7	68.6-82.0	169	0.03*	0.59
	Pooled	58.6	54.7-62.5	633	83.1	79.9-86.0	609	< 0.01*	1.00

during 30% spill than during 64% spill (59 vs. 83%, blocks 1-4 pooled; Table 5). As discussed

above, the combined estimates do not necessarily represent what might be obtained for a run-of-river mix of the two species.

In contrast to SPE, SLPE of both species was significantly greater during 30% spill than 64% spill (blocks 1-4 pooled; Table 6). We estimated juvenile steelhead SLPE to be 25 and 9% during 30 and 64% spill, respectively; yearling chinook salmon SLPE was 22 and 12%.

Table 6. Estimates ($p_{30\%}$ and $p_{64\%}$) of sluiceway passage efficiency (SLPE) for juvenile steelhead (STH), yearling chinook salmon (CH1), and both species combined (ALL) during two different spill discharges at The Dalles Dam, spring 1999. Spill discharges: 30%=30% 24-h spill discharge; 64%= 24-h spill discharge. CI=confidence interval. N=sample size. Significant differences (*) in SPLE between the spill discharges were evaluated using the Fisher Exact test (α=0.05).

| | | Spill Discharge | | | | | | | |
| | | 30% | | | 64% | | | (HO:$p_{30\%}$=$p_{64\%}$) | |
	Block	$p_{30\%}$	95% CI	N	$p_{64\%}$	95% CI	N	P	Power
STH	1	17.9	8.9-30.4	56	7.1	2.7-14.9	84	0.06	0.50
	2	34.8	23.5-47.6	66	10.5	4.7-19.7	76	< 0.01*	0.94
	3	33.8	23.2-45.7	74	3.7	0.8-10.4	81	< 0.01*	1.00
	4	17.7	11.2-26.0	113	13.4	7.3-21.8	97	0.45	0.13
	Pooled	25.2	20.5-30.5	309	8.9	6.1-12.4	338	< 0.01*	1.00
CH1	1	21.7	12.7-33.3	69	9.0	3.4-18.5	67	0.06	0.54
	2	21.3	12.9-31.8	80	9.3	4.1-17.5	86	0.05*	0.57
	3	18.6	11.0-28.4	86	8.7	2.4-20.8	46	0.20	0.31
	4	25.8	17.1-36.2	89	19.4	11.1-30.5	72	0.35	0.16
	Pooled	21.9	17.5-26.8	324	11.8	8.2-16.3	271	< 0.01*	0.91
ALL	1	20.0	13.4-28.1	125	7.9	4.2-13.5	151	< 0.01*	0.83
	2	27.4	20.3-35.4	146	9.9	5.8-15.5	162	< 0.01*	0.98
	3	25.6	19.1-33.1	160	5.5	2.2-11.0	127	< 0.01*	1.00
	4	21.3	15.9-27.6	202	16.0	10.8-22.4	169	0.23	0.25
	Pooled	23.5	20.3-27.0	633	10.2	7.9-12.9	609	< 0.01*	1.00

Estimates of SLPE at 30 and 64% spill did not differ between species (Fisher Exact test, blocks 1-4 pooled, P=0.35 and P=0.28). The pooled-species SLPE was significantly greater during 30%

spill than 64% spill (23 vs. 10%, blocks 1-4 pooled; Table 6).

Although significantly more juvenile steelhead and yearling chinook salmon passed through the spillway during 64% spill, 30% spill was more effective per volume of water passing through the spillway. During 30% spill, the ratios of juvenile steelhead and yearling chinook salmon passing through the spillway to the proportion of water spilled (i.e., spill effectiveness) were 2.2:1 and 1.7:1, respectively. The ratios at 64% spill were 1.4:1 and 1.3:1. The different values (i.e., slopes) at each spill level indicate the relationship between SPE and percent of total dam discharge being spilled is curvilinear and that SPE increases at a decreasing rate as the percentage of water being spilled increases.

Our ability to statistically detect differences in FPE, SPE, and SLPE between spill treatments was dependent on the magnitude of the difference between the passage estimates and the sample size. As the sample size and the difference between the proportions being compared get larger statistical power increases. Hence, the strongest comparisons are those where the data have been pooled and the differences between FPE, SPE, or SLPE estimates are the greatest (Table 4, 5, and 6). In the case of juvenile steelhead, where the difference in FPE estimates during the two spill levels was 4% (blocks 1-4 pooled; Table 4), the statistical power was low and the probability of statistically detecting such a difference was beyond the scope and intent of the present study. In contrast, the probability that we would be able to detect true differences in FPE estimates of yearling chinook salmon was much higher (Table 4). The power of the FPE comparisons are lower than the corresponding SPE comparisons with equal sample size because differences between the two spill discharges were more pronounced in SPE than FPE.

Diel Effects on FPE, SPE, and SLPE

Diel changes in passage conditions (day vs. night and adult vs. juvenile pattern) did not typically affect FPE, SPE, or SLPE significantly (Figure 7). However, since the two effects were confounded during the study, we were unable to examine them independently. The FPE and SLPE were typically greater for the daytime spill conditions than the nighttime spill conditions, but these differences were generally not significant (Fisher Exact tests, blocks 1-4 pooled, All $P>0.08$). The only significant difference between diel estimates of FPE or SLPE were of juvenile steelhead passing the dam during 30% spill (both $P<0.02$; Figure 6). No significant differences in SPE were found between the two spill patterns for either species (Fisher Exact

tests, blocks 1-4 pooled, All $P>0.16$). Fewer fish passed through the southern area of the spillay during the juvenile spill pattern than during the adult pattern (Figure 7). During 64% spill, 53% of the juvenile steelhead passed via the south half of the spillway and 35% passed via the north half, whereas 27 and 55% passed through these routes during the juvenile spill pattern. A similar shift in passage location was evident in data from juvenile chinook salmon. Sixty-four percent and 16% of the yearling chinook salmon passed through the south and north halves of the spillway, respectively, during the adult spill pattern, whereas 28 and 50% of the fish passed through these routes during the juvenile spill pattern. A smaller shift in spillway passage location of yearling chinook salmon was also evident between spill patterns during 30% spill discharge (Figure 7).
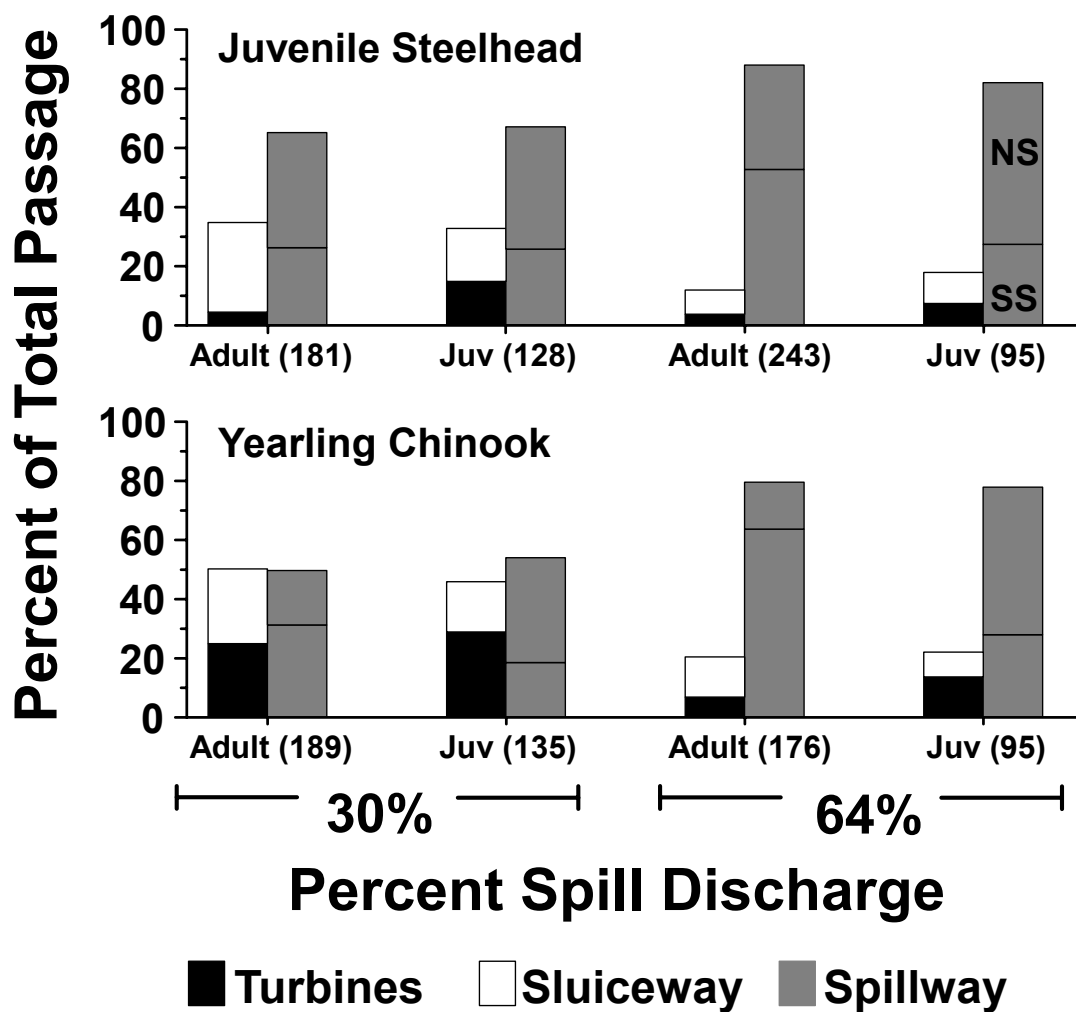
Figure 7. Percentage of radio-tagged juvenile steelhead and yearling chinook salmon passing through the powerhouse (sluiceway and turbines) and the spillway at 30 and 64% continuous 24-h spill discharge during the daytime adult and nighttime juvenile spill patterns, The Dalles Dam, spring 1999. SS=south spillway, NS=north spillway. Sample sizes are in parentheses.

Acknowledgments

We thank Marvin Shutters, Rock Peters, Miro Zyndol, and other COE personnel for their efforts in managing our contract and assisting in planning and executing this research. This work would not have been accomplished without the field efforts and technical assistance of Rip Shively, Richard Case, Cari Clements, Ken Gates, Amanda Harrison, and Russel Perry. Many thanks go to Rick Martinson of the National Marine Fisheries Service and his staff at John Day Dam for collecting and holding fish for this study.

References

Adams, N.S., D.W. Rondorf, S.D. Evans, J.E. Kelly, and R.W. Perry. 1998. Effects of surgically and gastrically implanted radio transmitters on swimming performance and predator avoidance of juvenile chinook salmon (*Oncorhynchus tshawytscha*). Canadian Journal of Fisheries and Aquatic Sciences 55: 781-787.

COE (U.S. Army Corps of Engineers), 1999. River Data. ONLINE. U.S. Army Corps of Engineers, Portland, Oregon, USA. Available:http://www.nwd-wc.usace.army.mil/-TMT/tdg_data/months.html [accessed June, 1999].

Hensleigh, J.E., R.S. Shively, H.C. Hansel, J.M. Hardiman, G.S. Holmberg, B.D. Liedtke, T.L. Martinelli, R.E. Wardell, R.H. Wertheimer, and T.P. Poe. 1999. Movement, distribution and behavior of radio-tagged juvenile chinook salmon and steelhead in John Day, The Dalles and Bonneville dam forebays, 1997. Annual report of research, U.S. Army Corps of Engineers, Portland District, Portland, Oregon, USA.

Holmberg, G.S., R.S. Shively, H.C. Hansel, T.L. Martinelli, M.B. Sheer, J.M. Hardiman, B.D. Liedtke, L.S. Blythe, and T.P. Poe. 1998. Movement, distribution, and behavior of radio-tagged juvenile chinook salmon in John Day, The Dalles, and Bonneville forebays, 1996. Annual report of research, U.S. Army Corps of Engineers, Portland District, Portland, Oregon, USA.

NMFS (National Marine Fisheries Service). 1998. Supplemental biological opinion: Operation of the federal Columbia River power system including the smolt monitoring program and the juvenile fish transportation program: A supplement to the Biological Opinion signed on March 2, 1995 for the same projects. Endangered Species Act – Section 7 Consulta-tion, National Marine Fisheries Service, Northwest Region, Seattle, Washington, USA.

Sheer, M.B., G.S. Holmberg, R.S. Shively, T.P. King, C.N. Frost, H.C. Hansel, T.M. Martinelli, and T.P. Poe. 1997. Movement, distribution, and passage behavior of radio-tagged juvenile chinook salmon in John Day and The Dalles Dam forebays, 1995. Annual report of research, U.S. Army Corps of Engineers, Portland District, Portland, Oregon, USA.

Whitney, R.R., L.D. Calvin, M.W. Erho, Jr., C.C. Coutant. 1997. Downstream passage for salmon at hydroelectric projects in the Columbia River Basin: development, installation, and evaluation. Prepared for the Northwest Power Planning Council, Portland, Oregon, USA. #97-15.

Zar, J.H. 1996. Biostatistical Analysis, third edition. Prentice-Hall, Inc. Englewood Cliffs, New Jersey, USA.

Appendix A

Appendix A1. Summary of the number of radio-tagged juvenile steelhead released (N) at Rock Creek during spring, 1999, and mean, standard deviation (SD), and range of the fork length (mm) and weight (g).

Date	Hour	N	Fork length (mm)			Weight (g)		
			Mean	SD	Range	Mean	SD	Range
05/06	0000	14	224.5	34.6	128-270	110.0	34.3	68.0-177.8
05/07	1300	15	224.0	19.3	185-265	97.8	26.6	56.0-169.6
05/07	2000	15	216.9	17.7	180-247	95.7	28.9	67.7-138.0
05/08	0900	15	215.9	29.9	164-258	-	-	-
05/09	2000	14	226.6	21.2	182-263	99.4	27.3	48.8-149.8
05/10	0800	12	228.6	24.2	191-287	109.6	43.3	64.4-227.5
05/10	2000	13	220.2	14.8	191-243	93.4	16.7	64.3-119.3
05/11	1100	19	219.9	19.7	191-273	94.1	26.0	56.5-170.4
05/12	2000	14	213.2	26.4	178-258	86.1	34.2	47.6-150.5
05/13	0800	11	213.9	19.8	177-246	83.1	21.1	44.0-111.5
05/13	2000	13	212.6	24.4	176-260	82.8	30.5	44.5-153.8
05/14	0800	19	213.2	24.8	174-275	85.4	34.7	28.8-186.4
05/15	2000	13	213.0	20.1	194-256	86.6	26.7	59.7-138.5
05/16	0800	9	211.6	50.4	117-286	95.8	56.6	45.8-198.1
05/16	2000	12	226.5	27.3	168-265	107.2	31.3	69.2-163.2
05/17	0800	12	205.6	14.6	183-234	71.5	22.3	45.8-134.4
05/18	2000	16	209.4	19.3	174-243	78.6	22.9	46.4-131.1
05/19	0900	12	222.2	29.7	182-274	98.2	39.7	55.9-179.4
05/19	2000	10	214.0	19.6	180-242	79.0	20.1	52.5-120.7
05/20	0800	21	217.7	25.4	181-275	90.2	35.0	47.0-176.7
05/21	0800	9	217.9	22.1	192-252	87.6	28.7	57.7-131.1
05/21	2000	10	202.9	20.2	167-236	67.4	19.7	35.6-103.8
05/22	2000	20	208.5	20.7	179-262	77.6	25.9	41.7-155.6
05/23	0800	18	206.1	21.1	174-256	72.4	25.2	43.5-138.2
05/24	2000	21	211.8	25.1	173-278	82.0	30.9	44.6-161.2
05/25	0800	14	206.3	19.4	182-250	74.4	23.5	52.0-132.0
05/25	2000	13	208.8	15.8	185-246	76.9	20.3	48.2-127.3
05/26	0800	26	207.8	25.7	163-276	77.3	36.4	35.8-197.5
05/27	2000	24	200.4	10.3	182-221	66.6	9.8	49.0-88.2
05/28	0800	12	206.5	21.2	181-267	73.0	25.8	47.6-148.7
05/28	2000	12	212.0	18.4	186-252	81.6	27.2	53.7-147.0
05/29	0800	21	222.1	24.0	187-258	93.2	31.0	57.5-145.6
Overall		479	214.0	23.6	117-287	85.5	30.7	28.8-227.5

Appendix A2. Summary of the number of radio-tagged yearling chinook salmon released (N) at Rock Creek during spring, 1999, and mean, standard deviation (SD), and range of the fork length (mm) and weight (g).

Date	Hour	N	Fork length (mm)			Weight (g)		
			Mean	SD	Range	Mean	SD	Range
05/06	0000	13	167.5	33.3	125-222	54.1	35.2	19.9-116.8
05/07	1300	15	152.3	22.1	123-195	40.3	18.3	18.5-78.4
05/07	2000	14	167.6	25.8	139-213	48.9	23.3	25.2-105.2
05/08	0900	15	174.2	28.9	142-222	-	-	-
05/09	2000	15	155.9	21.2	131-191	41.3	17.4	23.6-72.3
05/10	0800	12	165.9	21.0	146-208	46.3	16.7	31.0-77.6
05/10	2000	13	186.5	30.6	142-228	69.0	37.3	27.5-131.1
05/11	1100	20	184.9	21.6	141-220	69.4	25.3	27.1-112.7
05/12	2000	20	167.0	32.8	126-233	53.9	36.8	21.2-146.5
05/13	0800	10	178.7	30.5	136-223	60.8	31.0	25.6-113.8
05/13	2000	10	171.4	40.6	129-246	60.3	50.5	20.4-167.6
05/14	0800	20	166.5	22.2	140-235	49.3	27.4	26.8-150.6
05/15	2000	19	177.7	25.9	142-215	59.6	25.8	26.3-100.1
05/16	0800	10	165.7	23.3	141-216	46.6	20.2	25.8-87.1
05/16	2000	10	158.6	48.2	133-214	56.6	19.4	32.6-98.6
05/17	0800	21	170.0	18.5	135-230	50.2	19.7	22.5-125.4
05/18	2000	19	173.4	20.4	135-216	52.2	19.5	21.9-103.5
05/19	0900	10	151.8	8.1	145-167	33.6	7.3	21.0-45.4
05/19	2000	10	161.0	16.7	135-180	41.0	12.8	21.7-54.7
05/20	0800	20	163.4	20.2	137-201	43.3	16.2	25.6-74.8
05/21	0800	7	157.9	17.6	137-189	40.6	15.1	23.2-66.1
05/21	2000	9	156.9	17.1	135-190	38.1	15.1	23.5-70.8
05/22	2000	19	155.9	31.2	148-197	40.6	14.9	23.1-76.5
05/23	0800	21	160.7	15.4	132-194	40.3	12.4	20.3-69.3
05/24	2000	21	159.9	17.7	135-193	39.7	14.2	22.3-71.2
05/25	0800	10	162.9	13.1	134-176	40.0	9.1	21.2-49.6
05/25	2000	10	180.1	23.5	151-220	56.4	22.8	31.2-97.1
05/26	0800	24	162.7	20.2	134-210	42.0	18.0	22.3-92.9
05/27	2000	21	161.1	22.9	134-211	40.0	16.5	21.7-74.5
05/28	0800	12	166.7	22.8	135-220	44.3	24.2	22.2-108.8
05/28	2000	12	163.0	21.3	135-198	41.2	15.7	23.2-65.4
05/29	0800	7	156.1	17.4	140-181	35.2	12.2	24.8-54.3
Overall		469	166.0	25.1	123-246	47.8	23.7	18.5-167.6

Appendix A3. Summary of the number of radio-tagged juvenile steelhead released (N) at John Day Dam during spring,1999, and mean, standard deviation (SD), and range of the fork length (mm) and weight (g).

Date	Hour	N	Fork length (mm)			Weight (g)		
			Mean	SD	Range	Mean	SD	Range
05/06	2100	18	222.9	16.4	190-251	93.0	21.6	56.9-135.0
05/08	0900	18	225.8	20.8	194-280	101.0	31.0	62.2-181.4
05/09	2100	18	221.9	26.4	183-283	92.4	34.5	51.8-185.2
05/11	0900	20	206.8	30.2	118-254	82.4	27.1	42.6-143.7
05/12	2100	15	210.8	16.3	187-244	80.5	21.3	50.9-124.1
05/14	0900	14	222.4	20.5	200-270	96.2	32.1	69.0-179.2
05/15	2100	24	212.9	21.9	173-276	83.6	30.5	37.3-186.7
05/17	0900	22	212.9	21.8	174-254	81.0	25.4	42.9-123.8
05/18	2100	19	218.4	18.1	187-249	87.5	23.7	50.7-135.0
05/20	0900	19	214.2	24.2	157-258	83.7	30.1	30.9-150.4
05/21	2100	19	206.9	25.2	177-262	73.7	26.0	46.7-129.4
05/23	0900	19	208.6	20.3	188-260	77.3	25.2	51.9-144.7
05/24	2100	17	216.0	28.9	180-261	88.4	36.2	51.5-155.6
05/26	0900	19	211.9	22.2	184-265	79.6	27.6	48.8-151.6
05/27	2100	20	215.3	28.0	185-280	85.8	38.6	45.2-188.3
05/29	0900	19	214.4	29.9	167-281	82.5	35.7	39.7-171.8
Overall		300	214.9	23.8	118-283	85.2	29.7	30.9-188.3

Appendix A4. Summary of the number of radio-tagged yearling chinook salmon released (N) at John Day Dam during spring, 1999, and mean, standard deviation (SD), and range of the fork length (mm) and weight (g).

Date	Hour	N		Fork length (mm)				Weight (g)		
				Mean	SD	Range		Mean	SD	Range
05/06	2100	19		159.8	25.6	133-220		42.6	25.0	21.1-112.7
05/08	0900	18		185.8	37.1	129-230		77.9	39.0	19.7-137.6
05/09	2100	20		176.9	24.8	135-227		56.8	25.6	23.0-123.8
05/11	0900	19		183.1	14.1	153-210		59.5	17.1	29.5-91.5
05/12	2100	19		160.3	25.9	129-211		42.2	22.3	19.4-98.8
05/14	0900	18		170.7	21.6	135-205		50.1	17.8	22.5-83.3
05/15	2100	19		171.3	21.1	146-218		51.4	22.4	28.0-104.7
05/17	0900	18		179.1	17.5	160-223		56.6	20.0	39.4-110.3
05/18	2100	19		169.5	21.4	136-221		48.9	22.1	21.4-114.0
05/20	0900	19		159.5	18.5	127-197		39.2	14.7	21.1-71.4
05/21	2100	18		165.9	18.5	135-201		43.4	14.3	22.4-75.8
05/23	0900	18		162.9	23.5	136-219		42.5	21.0	21.0-103.1
05/24	2100	16		158.8	13.0	138-179		37.3	9.3	25.1-53.4
05/26	0900	17		155.8	21.9	129-226		36.3	19.9	20.1-105.3
05/27	2100	20		156.8	18.9	131-194		35.7	13.0	21.0-62.0
05/29	0900	20		154.4	20.1	132-230		35.3	16.9	20.7-71.3
Overall		297		166.9	23.7	127-230		47.2	23.3	19.4-137.6